DRIVERS OF ALBEDO CHANGE IN NORTHERN HIGH LATITUDE ECOSYSTEMS

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INTRODUCTION

- The Arctic is warming twice as fast as the global average[1], due in part to changes in albedo.
- Annual land surface albedo in the Northern Hemisphere has decreased ~0.01[2,3] since 2000, but the relative contribution of abiotic and biotic factors is unknown.
- Here we quantify the relative contribution of abiotic and biotic factors to decreasing terrestrial albedo across the Arctic and Subarctic (above 50°N).

METHODS

Table 1: Variables and corresponding data set(s) used for analysis.

	Mechanism	Data Set(s)
	Albedo	MCD43A3 V006
Explanatory variables	Enhanced Vegetation Index (EVI)	MOD13A1 and MYD13A1 V006
Explanatory variables	Fire	MCD64 V006, BLM AFS Historical Wildfires, Canadian National Fire Database
Explanatory variables	Growing Season Length	MCD12Q2 V006
Explanatory variables	Snow	MYD10A1 V006
Explanatory variables	Surface Water	MCD43A4 V006
Explanatory variables	Vegetation Continuous Fields	MOD44B V006
Explanatory variables	Land Cover Type	ESA CCI Land Cover Maps
Explanatory variables	Tree line	Ranson et al. 2014[6] Tree Cover at the Tundra Taiga Ecotone

Data Sets

- Most products were derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument (Table 1).
- Surface water calculated from MODIS reflectance bands according to the Superfine Water Index[4], which provides high contrast between surface water and non-water cover, including snow.

Analysis

- Analyzed a random stratified sample of 100,000 observations.
- Fit six separate generalized additive models, one for each month from April-September.
- The unit of observation was a 463 m MODIS pixel and the response variable was change in albedo.
- Each model had the same initial formula (below) and the best model for each month was selected using backward elimination.

$$\begin{gathered}\Delta albedo = \beta_0 + f_1(\Delta snow) + f_2(\Delta EVI) \\ + f_3(\Delta surface\ water) + f_4(\Delta\%tree) \\ + f_5(\Delta\%non-tree\ vegetation) + f_6(\Delta\%bare) \\ + f_7(\Delta growing\ season\ length) + f_8(landcover) \\ + f_9(tree\ line) + f_{10}(time\ since\ fire) + \varepsilon\end{gathered}$$

- Any variable in the best model that did not explain more than 1% of the variance was eliminated.
- The percent contribution of each variable (deviance explained, DE) was determined as follows:

$$\frac{DE_{full\ model} - DE_{model\ with\ variable\ removed}}{DE_{full\ model}}$$

Radiative Forcing

- The radiative forcing for each month was calculated using radiation data from the NASA POWER Project according to the following equation[5]:

$$RF = -surface\ flux\ * \Delta albedo\ * 20\ years\ * upwelling\ transmittance\ constant$$

REFERENCES

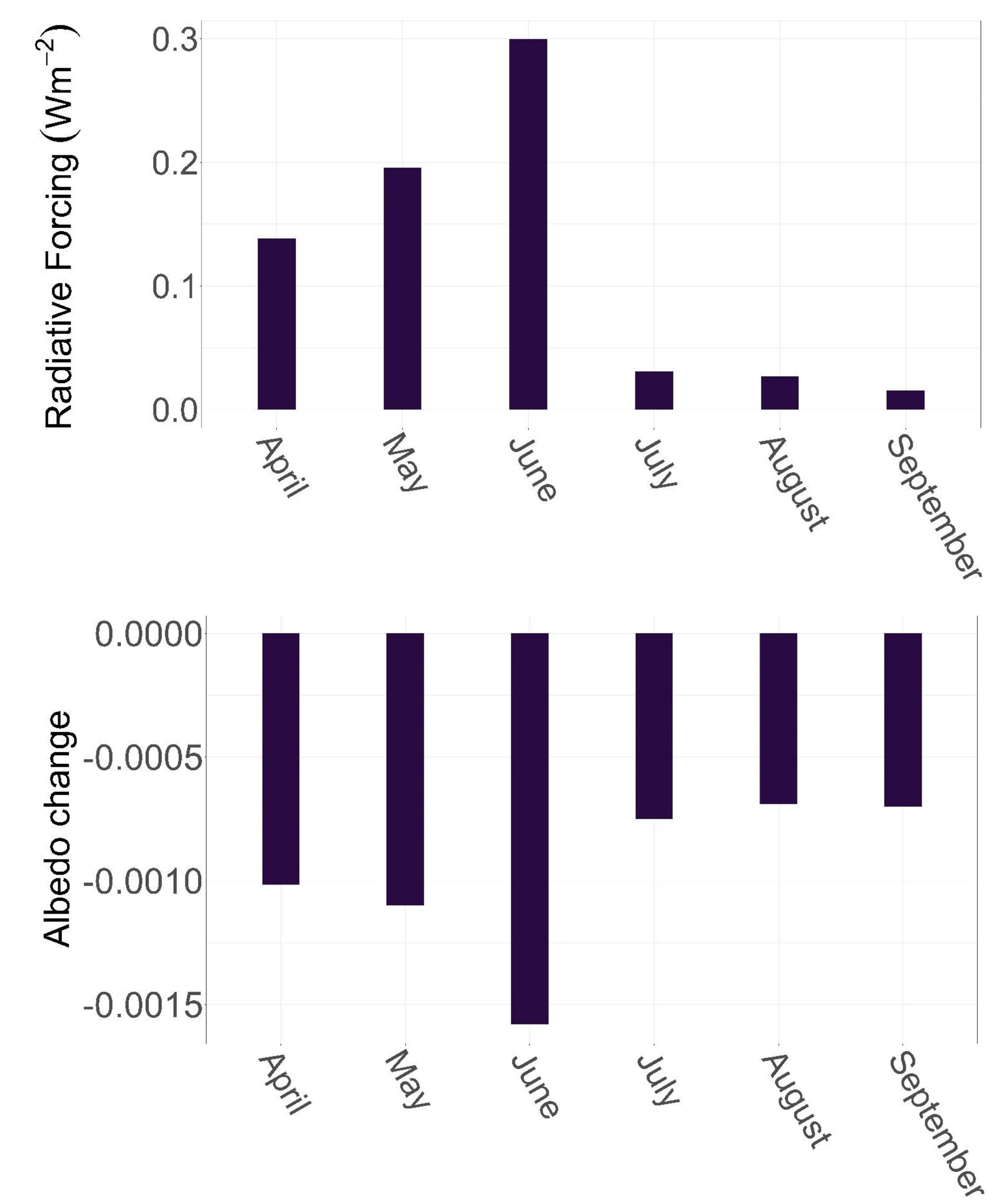
1 Osborne *et al.* E. Arctic Report Card 2018. (2018)
2 Zhang *et al.* Analysis of Global Land Surface Shortwave Broadband Albedo From Multiple Data Sources. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens* (2010).
3 Li *et al.*. *J. Geophys. Res. Atmos* (2018)
4 Sharma *et al.* DevelopSnow Cover and Vegetation-Induced Decrease in Global Albedo From 2002 to 2016ing Superfine Water Index (SWI) for Global Water Cover Mapping Using MODIS Data *Remote Sens.*(2015).
5 Bright and Kvalevåg. Technical Note: Evaluating a simple parameterization of radiative shortwave forcing from surface albedo change. *Atmos.Chem.Phys.* (2013).
6 Ranson *et al.* Tree Canopy Cover for the Circumpolar Taiga-Tundra Ecotone: 2000-2005 Data set. Available on-line [http://daac.ornl.gov] from ORNL DAAC, Oak Ridge, Tennessee, USA.

RESULTS

	Total Variation Explained (%)	Snow	Surface Water	Start of Growing Season	Fire	Land Cover	EVI	Snow or Water
April	44.7	81.9		1.3	2.2	6.6		8.1
May	51.1	11.8	15.8	3.7		4.1		64.6
June	67.5	15.3	25.6					26.6
July	35.8	7.1	73.4		4.9	2.6		12.1
September	59.6	16.2	31.5				1.4	50.9

Table 2: Percent contribution of each mechanism to circumpolar albedo change. Blank cells indicate the mechanism did not significantly contribute to albedo change or contributed less than 1%. Total variation explained is the deviance explained by the best model for each month.

Figure 1 (below): Average rate of albedo change over the circumpolar terrestrial region 2000-2019 (bottom) and associated globally-averaged radiative forcing (top).



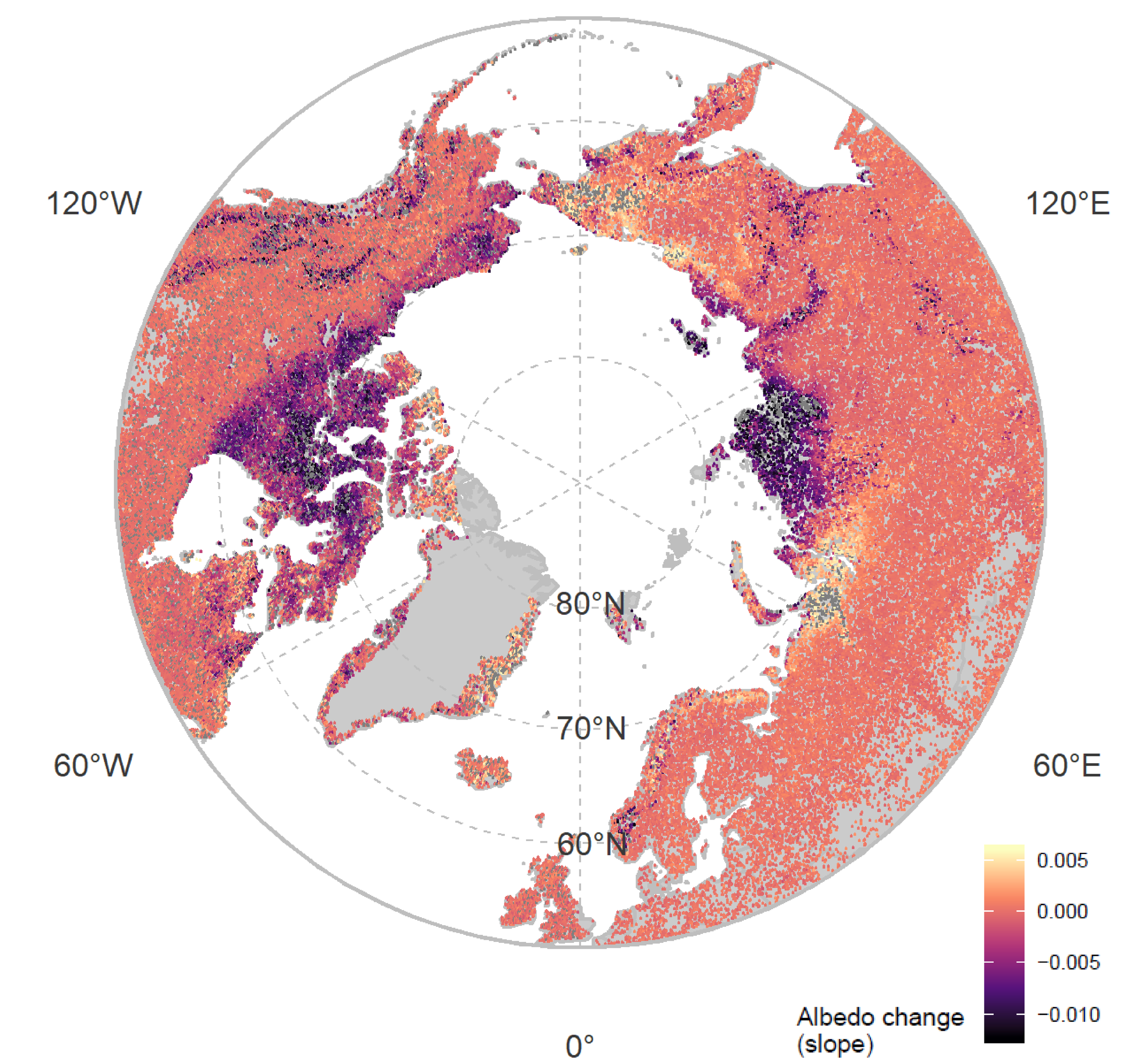


Figure 2 (right): Spatial distribution of June albedo change. Each pixel represents the slope of the average June albedo trend over time (2000-2019).

CONCLUSIONS

- For all months except April, change in surface water was the dominant driver of albedo change.
- Change in the start of the growing season contributed a significant but small proportion (1-4%) of albedo change in April and May.
- In July, the contribution of biotic mechanisms (fire and land cover type) to albedo change are on the same order of magnitude as the contribution of snow.
- Changes in vegetation greenness significantly contributed to albedo change in September.
- Albedo change in the study area over the past 20 years resulted in an annual global radiative forcing of 0.06 Wm^{-2}, which is twice the increase in radiative forcing due to global CH_4 emissions over the same time period.